Cassini Maneuver Experience: Finishing Inner Cruise

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Abstract

The Cassini project is an international effort to study the planet Saturn and its moons with an orbital tour. The Cassini spacecraft is made up of the orbiter and the Huygens probe. The European Space Agency's (ESA) Huygens probe will be delivered to Saturn's moon Titan by the spacecraft. This is the first mission to visit Saturn since the flybys made by the two historic Voyager spacecraft in 1980 and 1981. Cassini was launched on October 15, 1997 and will arrive at Saturn in 2004, the climax of a long journey. This interplanetary trajectory to Saturn requires four gravity-assists, two from Venus, one from Earth, and another from Jupiter. This trajectory is referred to as 97 VVEJGA.

There are seven years between launch and arrival at Saturn. There are roughly 6.5 months between launch and the first Venus swingby, 14 months between the two Venus swingbys, and 55 days between the second Venus swingby and the Earth swingby. The Jupiter swingby is about one-third of way into the subsequent 5 years. Although no science investigations are planned, there are many activities to be accomplished within this time, including the execution of 21 TCMs. Several of the TCMs during cruise and the final approach to Saturn are deterministic, viz. have a non-zero mean $\Delta \mathbf{V}$

Cassini's maneuvers are executed in a turn-and-burn mode. The spacecraft is three-axis stabilized and, for maneuvers, thrust is always to be applied approximately along the spacecraft's -Z-axis. To orient this thrust in the desired direction, the entire spacecraft must be rotated, resulting in the following sequence of events: turn (or wind), burn, and turn back (or unwind).

Prelaunch plans and experience during early cruise were published previously. Now that the inner-solar-system phase of cruise is finished – the spacecraft is in the Earth-to-Jupiter leg – further operational experience of the Cassini mission is reported, with a focus on the deep space maneuver (DSM) and the seven subsequent trajectory correction maneuvers (TCMs). A second focus is the improvement of Cassini's TCM execution error statistics.

The DSM was performed near aphelion to lower the perihelion of the trajectory. This changes the subsequent swingby geometry and raises the Venus-swingby velocity to make possible an energy gain on both the first and the second Venus swingbys. TCM-6 corrected for execution errors in the DSM and removed a Earth-bias in the trajectory. Execution errors in TCM-6 where corrected by TCM-7, the last maneuver before the second Venus swingby. Between the Venus-2 and Earth swingbys, four maneuvers were executed, TCM-9 through TCM-12, each of which were primarily Earth-bias-removal maneuvers. Errors in the Earth swingby were corrected by TCM-13, which was targeted to a B-plane at Jupiter.

The execution errors for these maneuvers has so far been at the level of the prelaunch execution error analysis or better. As such, TCMs -3, -4, and -8 were canceled.

After the DSM, a small (~1°) pointing bias was observed and subsequently corrected by adding an extra rotation to the maneuver sequence.

This maneuver analysis separates execution errors into two categories: magnitude and pointing. The statistical models for these errors is updated based on the best estimates of the maneuvers discussed above. This new model will provide more realism to predictions of the fuel required to navigate the tour of Saturn's system.